E1-A

Oscillating circuit

Oscillation starting stability of crystal oscillator

Item to be checked

① *Check that the oscillation allowance is satisfactory secured (negative resistance: $|-R_Z|$).
**$|-R_Z| = R_V + R_S$, R_V : Externally-provided resistance as the oscillation limit (See the figure below.)
R_S: Equivalent impedance of crystal
② Check that the performance of ① has been confirmed using the actual product **.
** (The capacity floating substance of the substrate must be included.)
③ Check that high and low-temperature performance has been confirmed for ②.
(under the conditions of operation guaranteed temperature range and the upper and lower temperature limits)
④ Check that the crystal to be used has been subjected to the temperature-cycle-aging test as specified.
⑤ Check that Rs has been measured under the oscillating power conditions in both the practical range and the micro range.

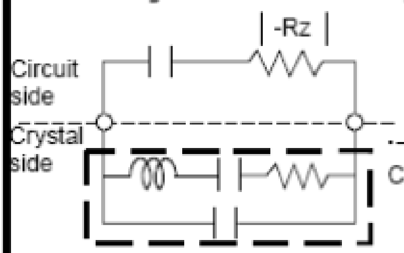
Reference value

① "$|-R_Z| > \alpha$ Rs" must be satisfied in the operation guaranteed temperature range.
α (oscillating allowance) must be determined after consultation with the crystal supplier concerned, in view of the priority of the equipment and the target market defective rate. From the actual result so far, α > 5 to 10 must be satisfied.
② The crystal to be used for automobile must be subjected to the temperature-cycle-aging test between -40 °C and 105 °C for 10 cycles MIN.
(The accepted test results have a large effect on reducing deterioration with age of Rs.)
③ Rs must be guaranteed under at least two confirmation conditions in the practical oscillating power range and in the micropower range (10-2 µW order) to satisfy the standard (to eliminate Rs variations with the oscillating power conditions).

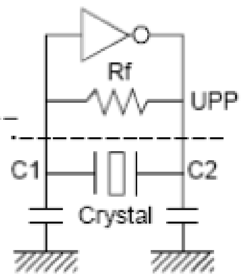
Key points

① Matching between the crystal and the product (substrate and elements) must be requested to the crystal supplier by presenting the product at the initial development stage.
② When any change has been given to the substrate, the request in ① must be made again for re-matching.
③ Matching between the crystal and the product must be confirmed after identifying variations of each element (due to the individual difference, temperature characteristics, or deterioration with age). As for the microcomputer and crystal oscillator, the oscillation characteristics must be confirmed using limit samples.

Explanation



Crystal oscillation equivalent circuit



Crystal oscillation circuit

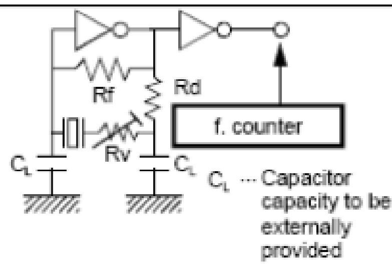
Oscillation condition

$|-Rz| > \alpha$ Rs ... ①
↓

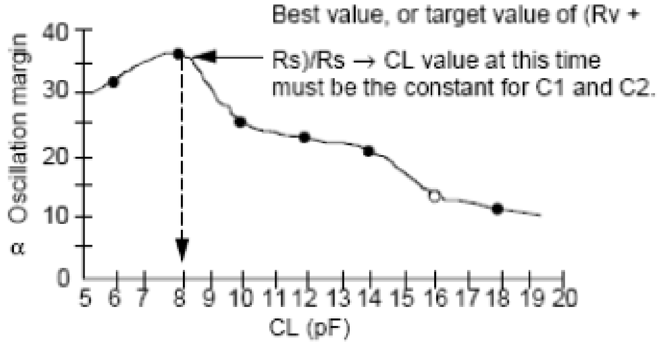
($Rz = gm/\varpi^2 C_1 C_2$)
$\varpi = 2\pi \cdot fo$
↓
(Oscillating frequency)

If the | -Rz | value is set too low (or allowance α), the expression ① above cannot be satisfied depending on the Rs values (including deterioration with age), which causes some circuits to fail to start oscillating.

. How to measure and determine the oscillation allowance (in charge of crystal supplier) : After additionally providing the variable resistance Rv, measure the start limit resistance.



Rv: Start limit resistance
Rs: Equivalent resistance of crystal
Rd: Pattern impedance
α : Oscillation allowance $|-Rz| = Rv + Rs$
$\alpha = |-Rz| / Rs$

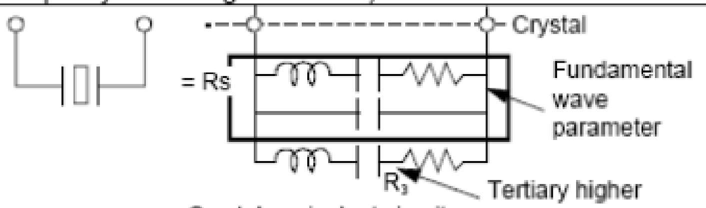


Relationship between oscillation allowance and load capacity

Determine the constant of circuit by conducting the above procedures using the substrate assembly (including the capacity of floating substance).

Notes

① If the | -Rz | is set too high, or if the instructions on fundamental wave oscillation or higher harmonic oscillation (tertiary elements) are not clearly given, accidents due to higher harmonic oscillation may happen. So, the details must be determined in close collaboration with the crystal supplier.



Crystal equivalent circuit

② When multilayer substrate is used, in particular, the oscillation allowance will not be so high, because the amount of floating substance of the substrate is larger. Thus, it is recommended to request matching between the crystal and the product to the crystal supplier at the initial development stage.

Oscillating circuit

Abnormal oscillation prevention in overtone oscillation circuit

E2-A

Item to be checked

① Check that overtone oscillation is applied to the applicable crystal. (See the note below.)
② Confirm that the crystal supplier has checked that a difference of 3 dB MIN between primary oscillation and sub-oscillation levels is satisfied in its manufacturing process.
③ Confirm that the crystal supplier has described the following in the delivery specifications issued by the supplier: "A difference of 3 dB MIN between the primary and sub-oscillation levels of crystal oscillator is guaranteed in the control unit operating temperature range."

Reference value

The following relationship must be satisfied in the control unit operating temperature range:
(Primary oscillation level) - (sub-oscillation level) > 3 dB

Key points

Confirm that an agreement on the sub-oscillation level has been made between the control unit supplier and the crystal supplier at the development stage.

Explanation

Fig. a shows a general overtone oscillation circuit (Colpitts type). It is necessary in the overtone oscillation circuit to determine a constant so that the frequency characteristic fa of the tank (LC resonance) circuit consisting of La and Ca is the capacitive reactance in the applicable oscillation frequency, in order to obtain the higher-harmonic order frequency (tertiary order in Figures a and b). To obtain tertiary harmonic oscillation, for an instance, fa must be set at the center between the fundamental wave fo and the frequency 3fo being three times higher than fo, as shown in Fig. b.
When the crystal oscillator is oscillated in overtone mode (tertiary, quinary, etc.) even if the oscillator was originally made for thicker slip vibration, some other oscillation modes such as border vibrations are also detected. As might be expected, the vibration frequency of those modes is different from that of the intended mode (primary vibration), which is called the sub-oscillation, or spurious vibration (frequency). Generally, the sub-oscillation is not generated when a difference between the primary and sub-oscillation levels is 2 dB MIN. So, 3 dB MIN is used as the reference value by the crystal supplier.
Fig. c shows an example of measured data in which the difference between the primary and sub-oscillation levels is 3.84 dB, satisfying the reference value.

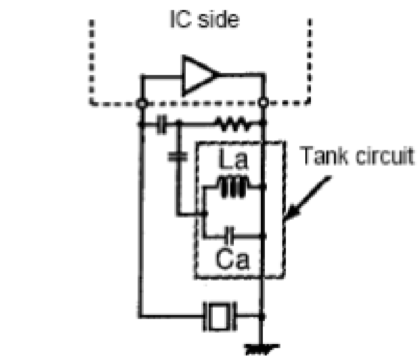


Fig a: Basic configuration of evertone oscillation circuit

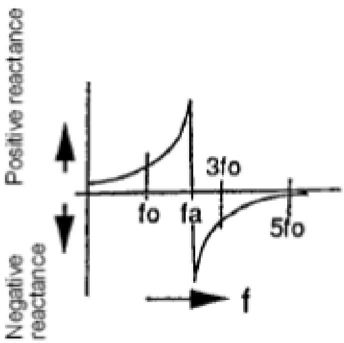


Fig. b: Frequency characteristics of tank circuit

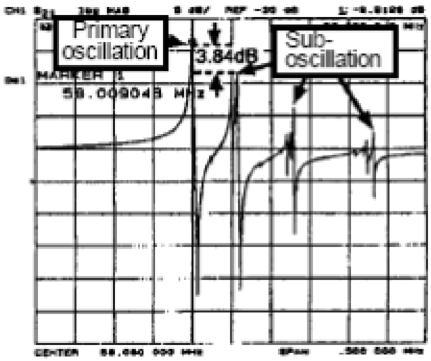
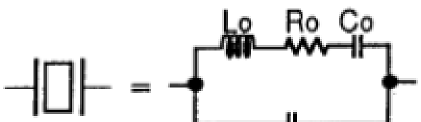


Fig. c: An example of measurement of primary and sub-oscillation levels

Notes

A crystal oscillator is shown as an equivalent circuit as in Fig. d, showing an inductive reactance between the series resonance frequency (fo) and the parallel resonance frequency (fp) as in Fig. e, and oscillates in this frequency range. However, the crystal oscillator also has resonance points at the frequency being three times or five times higher than fo as in Fig. f, showing the inductive reactance. It is thus possible to generate oscillation in the frequency ranges of f3 and f5 as well by providing the circuit with the capacitive reactance characteristics in these frequency ranges. This is called overtone oscillation.



$$fo = \frac{1}{2\pi\sqrt{LoCo}}$$

$$fp = \frac{1}{2\pi\sqrt{LoCo}}\sqrt{\frac{Cs+Co}{Cs}}$$

Fig. d: Crystal oscillator equivalent circuit

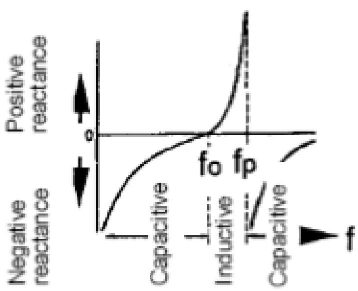


Fig. e: Reactance frequency characteristics of crystal oscillator

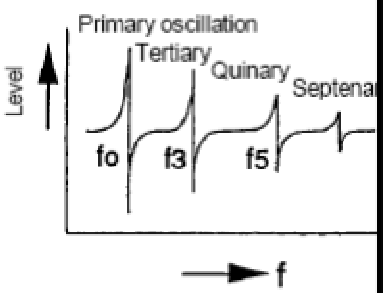


Fig. f: Overtone oscillation vibration level

Oscillating circuit

Oscillating stability of ceramic oscillator

E3-A

Item to be checked

Confirm the following items with an actual product.

① The oscillation characteristics (oscillating level, oscillation starting voltage, and oscillation rise time) must be confirmed in consideration of the variations of each element (due to individual difference, temperature characteristics, and deterioration with age).

- Check that the characteristics of ceramic oscillator (Ro and Ra) and microcomputer/IC (gain) have been confirmed with limit samples.
- Check that the oscillation characteristics have been confirmed at high and low temperatures (in the operating guaranteed temperature range, and between the upper and lower limit temperatures).

②The oscillation allowance in Item E1-A above must be confirmed by the negative resistance method.

③The open loop characteristics must be confirmed in consideration of the variations of the oscillation wave and spurious wave.

⇨ The measuring conditions such as input voltage and applied impedance must be described. Also the temperature characteristics of elements confirmed at normal temperature must be considered.

- Check that the loop gain allowance has been satisfactorily secured. (Loop gain with oscillation frequency: fosc = phase 0°: See Fig. 3 in the explanation column below).
- Check that the loop phase allowance has been satisfactorily secured. (Loop phase amount with gain 0 dB: See Fig. 3 in the explanation column.)
- Check that the loop gain difference between the oscillation wave and spurious wave has been satisfactorily secured.

Reference value

① The oscillation level (clock X_{out}-grounding, X_{in}-grounding amplitude) must exceed the HIGH-level minimum standard and the LOW-level maximum standard values for input and output of the microcomputer (IC), under the conditions of operation-guaranteed voltage and temperature ranges in consideration of variations of the oscillation circuit elements. Also, any symptom of abnormal oscillation* must not exist at oscillation starting. * Generation of spurious elements

② Negative resistance method I -Rz I > α Rs, α (Oscillation allowance) > 3 to 5 shall be met.

③-1 Loop gain allowance target ... 5dB (Worst sample) ~ 10dB (Type sample) MIN

③-2 Loop phase allowance target ... I -20 I deg (Worst sample) ~ I -40 I deg (Type sample)MIN

③-3 The loop gain of the oscillation frequency must be higher by 5 dB MIN than that of the spurious frequency (tertiary and quinary overtone elements). It is perfectly acceptable when the spurious gain is 0 dB MAX.

Key points

1) Matching between the ceramic oscillator and the product (the microcomputer and the ECU substrate) must be requested to the oscillator supplier by presenting the product. When any change in the substrate has been given, matching confirmation must be requested again.

2) When a lower frequency value is selected in the microcomputer which has an oscillation-frequency selective function, the spurious oscillation will easily occur due to surplus loop gain. So, this must be carefully studied in matching confirmation.

Explanation

Oscillation conditions
(Compare the following with Figures 2 and 3 for reference)

○Loop gain G = α . β ≥ 1
... The loop gain must be 0 dB MIN at fosc. → Gain allowance 5 ~10 dB

Trade-off relation

○Amount of phase shift θ = θ1 + θ2 = 360° Xn
... The phase 0° must be attained at fosc. → Phase allowance -20 ~ -40 deg

$$fosc = 1/2\pi\sqrt{L1\ C_1\ (C_0\ CL)\ /\ (C_0\ C_1 + CL)}$$

Oscillation frequency However, CL = CL1CL2 / (CL1+CL2)

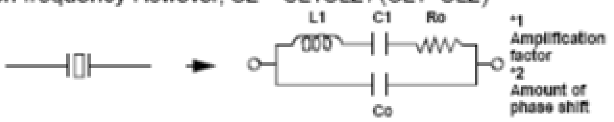


Fig. 1: Ceramic oscillator equivalent circuit

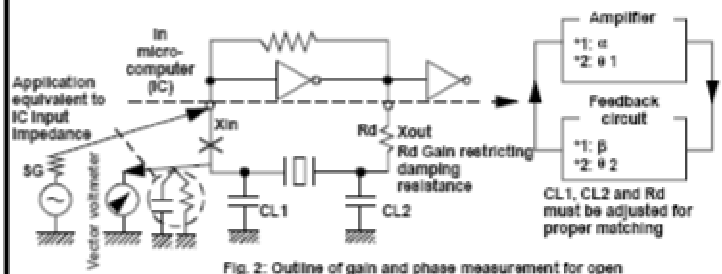


Fig. 2: Outline of gain and phase measurement for open loop characteristics of oscillation circuit

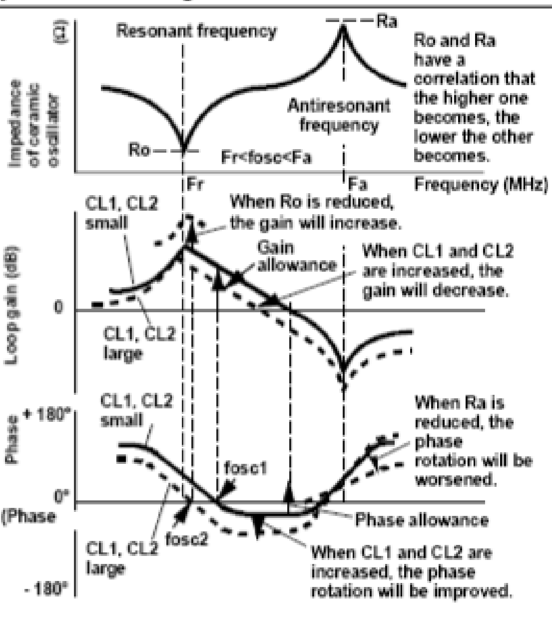
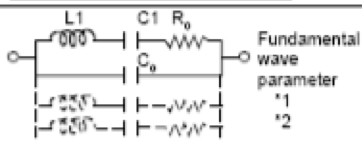


Fig. 3: Relation between gain/phase characteristics of oscillation circuit and effect factors

Notes

- The phase rotation of the ceramic oscillators is relatively worse than that of the crystal oscillators, because the antiresonant resistance Ra is smaller. If the gain is set too high in matching confirmation, the phase will be reduced too much, generating the spurious oscillation (tertiary and quinary elements) easily. To prevent this problem, it is important to keep a balance between the gain allowance and the phase allowance, and to reduce the gain of the spurious wave substantially in comparison with that of the oscillation wave.



*1: Spurious wave with tertiary element
*2: Spurious wave with quinary element

○ Oscillation stability conditions

		Ro	Ra	C_{L1}, C_{L2}	Microcomputer gain
Fundamental wave oscillation	Gain allowance	Small	—	Small	Large
	Phase allowance	—	Large	Large	—
Spurious oscillation resistance		Low	High	High	Low

→

○ Matching confirmation conditions in consideration of variations

		Ro	Ra	C_{L1}, C_{L2}	Microcomputer gain
Fundamental wave oscillation	Gain allowance	max product	—	tolerance max	Min product
	Phase allowance	—	min product	tolerance min	—
Spurious oscillation resistance		max product	min product	tolerance min	Max product